Indication of the state of spontaneous combustion

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Abstract *: In the years 1986-2001, the research activity called "Cataloguing of seams from the viewpoint of their tendency towards spontaneous combustion" had run in the Ostrava-Karviná District (OKR) in the Czech part of Upper Silesian Basin. Totally 62 coal samples were documented. The gas images of gaseous products of thermal oxidation of coal samples containing the gases CO, CO2, decrease of O2, H2 and saturated and non-saturated gaseous hydrocarbons C2-C4 created an integral part of catalogues. For the purposes of these gas images evaluation two computer databases and two computing programs for evaluation of basic materials were created. In content of the article the selected binary ratios of gases are emphasized which can be applied in the OKR practice for indication of temperature of spontaneous combustion focus.*

The very beginnings of utilization of gaseous products of coal heat stress for indication of the state of spontaneous combustion in the environment of a mine reach into the first half of the last century when the author Graham mentioned the dependence of carbon dioxide and carbon monoxide development on the oxygen decrease in coal oxidation. It resulted in the Graham's numbers known up to now (Graham, 1920). The proposal of utilization of gaseous hydrocarbons for indication of spontaneous combustion came from the contribution of the author (Kittagowam, 1959) on the 10^{th} international conference of research institutes on mines safety in Pittsburgh . Later, this knowledge was confirmed in the whole number of countries with developed mining industry, e.g. in Great Britain (Chamberlain, 1970, 1973, 1976), Canada (Chakravorty, 1978) etc. In the Czech Republic, these problems were dealt with by Výzkumný uhelný ústav (Research Coal Institute) in Ostrava (Schreiber, 1987) and Hlavní báňská záchranná stanice (Main Mining Rescue Station) in Ostrava. Into the practice of OKR the bar graph of spontaneous combustion gases development of Hlavní báňská záchranná stanice (Main Mining Rescue Station) in Ostrava, HBZS a.s., Ostrava was implemented, according to (Hajník, 1987).

In the years 1986-2001 the research activity had run in the Ostrava-Karviná District (OKR) in the Czech part of the Upper Silesian basin, called „Cataloguing of seams from the viewpoint of their tendency towards spontaneous combustion". Totally 62 coal samples were processed. The gas images of gaseous products of thermal oxidation of coal samples were an integral part of the catalogues content. The coal sample of the weight 150 g, fraction 0,2 - 2,0 mm was placed, in laboratory conditions, into the reactor of air thermostat and was heated gradually in the intervals of 20 ^{o}C at sucking of 20 ml.min^{-1} of air. In each coal sample 10 gaseous components were observed (CO_2, CO, CH_4, C_2H_6, C_3H_8, n-C_4H_{10}, i-C_4H_{10}, C_2H_4, C_3H_6, since the year 1999 also H_2), and namely at 18 temperatures up to the year 1988 (range 40 - 380 ^{o}C) and in 9 temperatures since the year 1991 (range 40 - 200 ^{o}C). The gases development were documented in tables and graphs in values of gases concentrations measured and in values of gases quantities released converted on coal sample dump and time in the form of ml.t^{-1}.min^{-1}. The summarized description of all coal samples and the methods used was given in the monographic work (Adamus, 2004).

For the purposes of these gas images evaluation the computer databases and computing programs were created. In the program environment of MS Excel the mean values

for 62 gas images were computed and the minimum as well as maximum values for each gas were found out.
One of the outputs of this evaluation was the common graph of average development of gas quantity released from coal samples OKR given in Fig. No. 1 including detail.

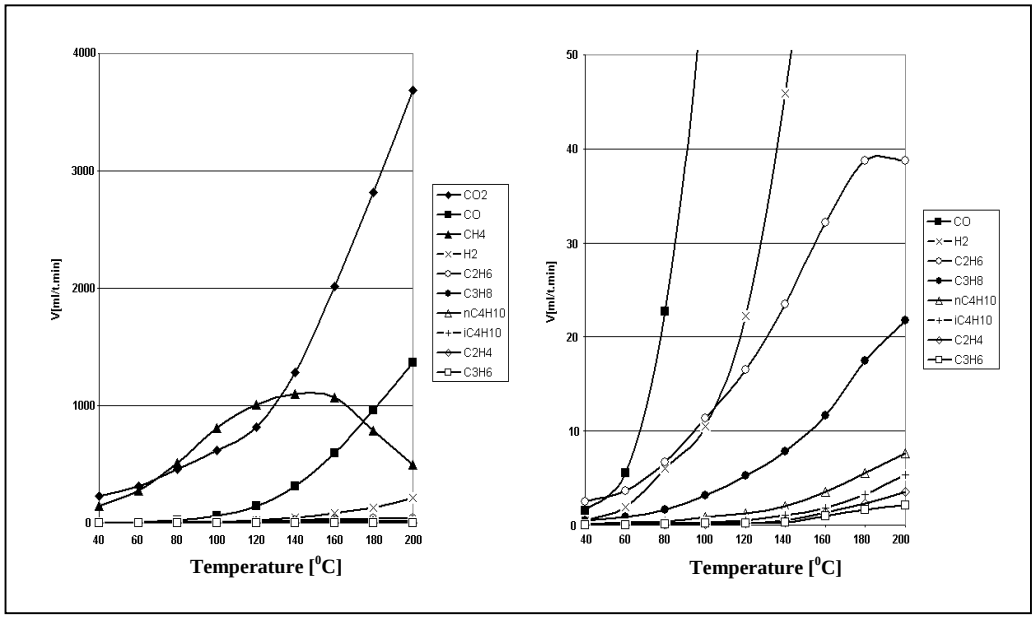

Fig. No. 1. Average development of thermal oxidation products of OKR coal samples (Šancer 2002).

The graphical outputs of the OKR database were also generated for single gases and their ratios. The example of this evaluation is given in Fig. No. 2 in the form of courses of released CO quantity of all 62 coal samples from OKR and their average. The course of binary indicator CO_2/CO which was used in computing program "Indication" is given in Fig. No. 3. In case of this indicator the variation range of values (dispersion variant) is more significant than in CO and required the filtering off. The Figure 3 illustrates the courses of the indicator CO_2/CO of 39 coal samples and their average. In the program environment MS Excel all gaseous components and binary indicators, with the exclusion of inversion indicators, were evaluated in the same way.

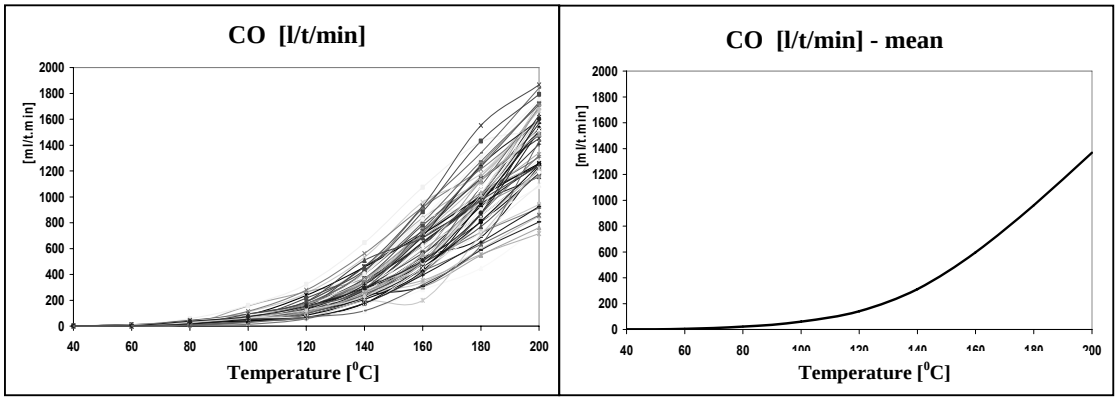

Fig. No.2 The course of released CO quantities of the OKR coal

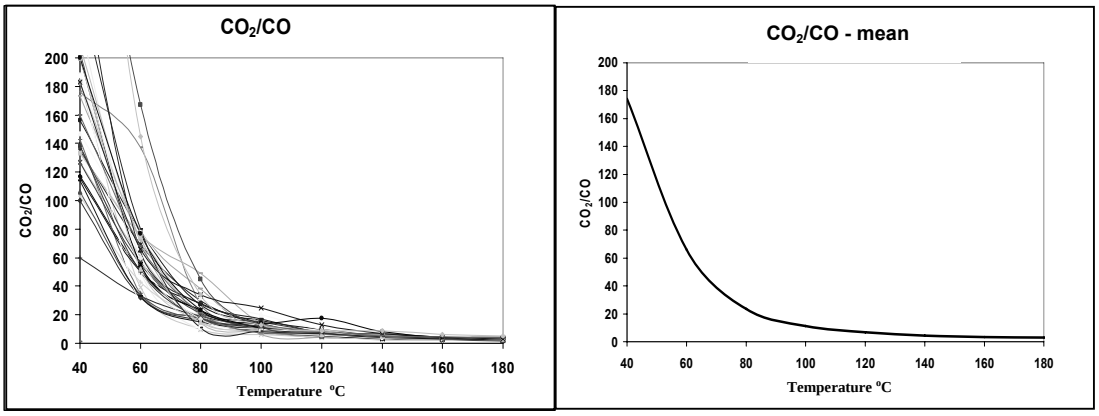

Fig. No. 3 The course of CO_2/CO binary indicator

With the help of computing programs the associations between the development of gaseous products and physically-chemical characteristics of coal mass and between the development of gaseous products and locality of coal samples taking were found. The statistical methods did not confirm the provable connections between the development of gases and parameters of composition and structure of coal but they confirmed a certain dependence of gases development on the sampling locality the result of which was the recommendation to make use of the database in the way of selective data selection according to the locality of coal sampling. One of the computing programs (Štecker, 2002) enables the presentation of tables and graphs of the courses of gases quantities released and binary dimensionless indicators according to the selection of coal district, mining enterprise, seam, floe, working place, gaseous component and gases ratios. At the same time, 255 courses of gaseous components, respectively gases ratios in one graph can be illustrated. With the help of the program the courses of gaseous products of thermal oxidation according to gaseous components and selected dimensionless indicators for the entire OKR were illustrated and documented, further selectively for the OKR seams and selectively for seams and mining enterprises. The operative work with the program confirmed the conclusions of statistical evaluation in the sense of the releasing similarity of thermal oxidation gaseous products in relation to locality of sampling. The example is given in Fig. No. 4 and Fig. No. 5. In Fig. No. 4 the course of binary dimensionless indicator C_2H_4/C_2H_6 of all coal samples processed is presented. Figure No. 5 illustrates the selected courses of binary indicator C_2H_4/C_2H_6 of coal samples of the seam No. 40 of the Dukla Mine. The course of the indicator in question, Fig. No. 5, can be considered as the usable binary indicator for determination especially of temperature of 280 ^oC of spontaneous combustion focus in given seam and locality.

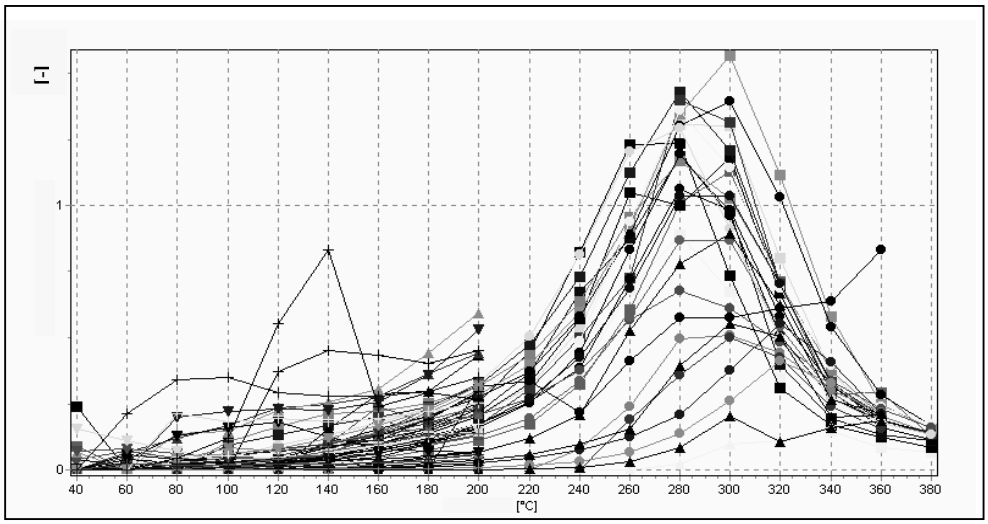

Fig. No. 4 The course of binary indicator C_2H_4/C_2H_6 of the OKR samples

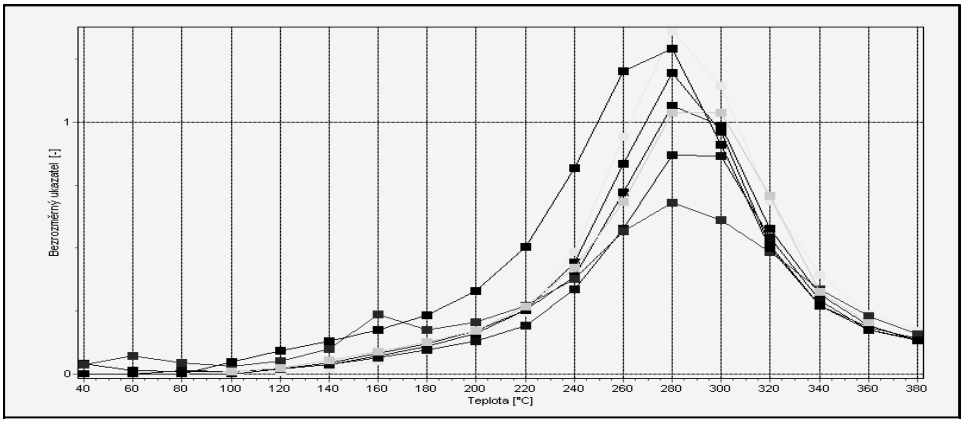

Fig. No. 5 The course of binary indicator C_2H_4/C_2H_6 of the seam No. 40 of the Dukla Mine

The computing program CnHm was equipped with the magnifying glass for magnification of the sector of graphs part for the cases of concealed overlapping of curves. With the help of magnifying glass the parallel runs of several binary indicators of coal samples of the seam No. 40 were found. The figure No. 6 gives the course of indicator C_2H_6/C_3H_8 in original presentation and in detail illustrated with the help of magnifying glass with subsequent definition of selected border values of given indicator. In the same procedure the similar parallel runs in binary indicators C_2H_6/C_2H_4 a C_2H_4/C_3H_8 were found.

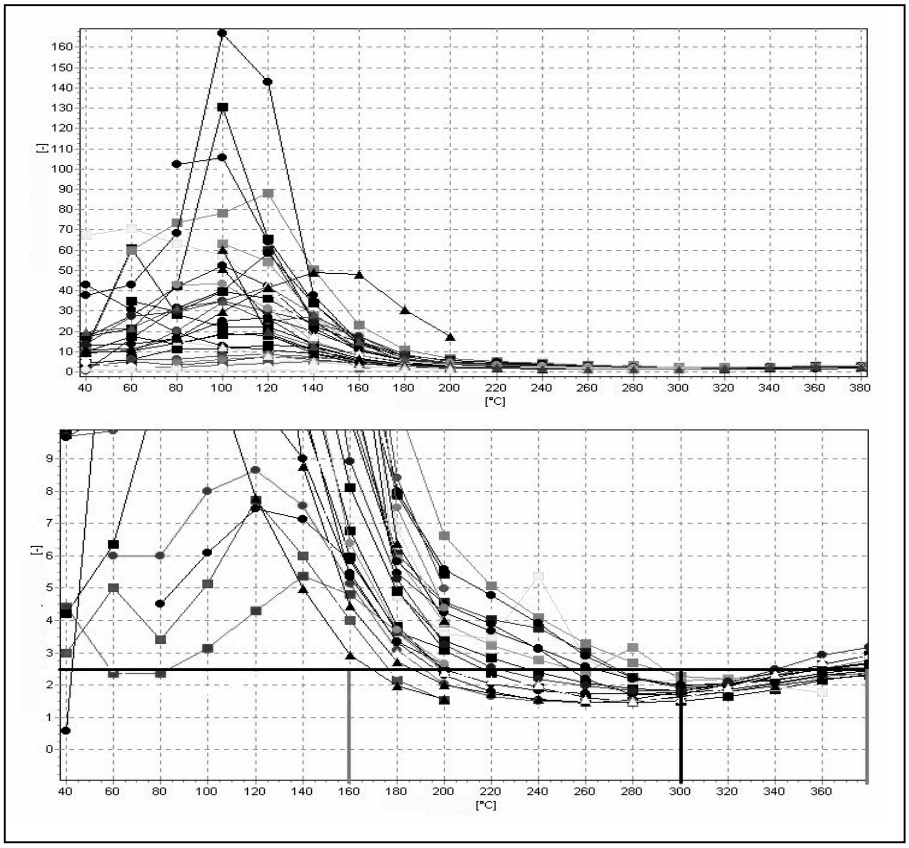

Fig. No. 6 The course of binary indicator C_2H_6/C_3H_8 of samples of the OKR seam No. 40

From the courses and border limits of selected binary indicators the following relationships to indicated temperature valid for the seam No. 40 in OKR could be defined:

- **C_2H_6/C_3H_8 (ethane/propane),**
  binary dimensionless indicator C_2H_6/C_3H_8 (Fig. No. 7) has the decreasing tendency in the temperature interval of 140 - 300 ^oC. In case that the indicator reached the value 2,5 and lower in decreasing tendency, the temperature in the interval of 160 – 300^oC will be indicated. If the tendency of the indicator development was not evaluated, the temperature in the indicator value of 2,5 and lower in the interval of 160 – 380^oC will be indicated (the uncertainty in given evaluation was given by 3 dissentient samples from 30 samples).

- **C_2H_6/C_2H_4 (ethane/ethylene),**
  binary dimensionless indicator C_2H_6/C_2H_4 has decreasing tendency in the temperature interval of 160 - 260^oC. In case that the indicator reached the value 2,0 and lower in decreasing tendency, the temperature in the interval 220 - 260^oC will be indicated. If the tendency of the indicator development was not evaluated, the temperature in the indicator value of 2,0 and lower in the interval of 220 - 340^oC will be indicated (the uncertainty in given evaluation was given by 1 dissentient sample from 21 samples).

- **C_2H_4/C_3H_6 (ethylene/propylene),**
  According to the binary dimensionless indicator C_2H_4/C_3H_6 the temperature of spontaneous combustion focus of 300°C and more will be indicated, in case that the indicator reached the value 1,0 or lower in decreasing tendency (the uncertainty in the interval over 120°C was given by 2 dissentient samples from 21 samples).

For utilization of the above mentioned dimensionless indicators in practice the evaluation procedure of operation situation can be proposed, and namely in the following order:

1. C_2H_6/C_3H_8 (ethane/propane),
2. C_2H_6/C_2H_4 (ethane/ethylene),
3. C_2H_4/C_3H_6 (ethylene/propylene).

The program CnHm can be applied in practice as the tool in evaluation of samples of mine atmosphere gases by comparison of their binary indicators with the courses of indicators of gas images verified in laboratory. The program CnHm enables the editing of database of gas images what can be used individually in supplementing the database with mining enterprises.

The utilization of binary indicators obtained from laboratory gas images of coal thermal oxidation requires certain experience in their application in practice. The gas images of thermal oxidation method represent, in each from temperatures evaluated, the homogenous state of coal mass, as to the temperature. The indication gases of spontaneous combustion in mine conditions are released under the conditions of non-homogenous focus of spontaneous combustion as to the temperature and, as a rule, they represent the mixture of gaseous components released from the whole volume, or spontaneous combustion area. For these reason, it is suitable, in evaluation of indication gases of mine atmosphere, to use pairs of gases near to their characteristic temperature of releasing (see Fig. No. 1). E.g. in early stage of spontaneous combustion, it is suitable to use the binary indicator CO_2/CO. This indicator can, in case of increasing temperature of the spontaneous combustion focus center, indicate also further the relatively low temperature because the released gases quantity from the focus edge with lower temperature takes share in its value. For evaluation of relatively high temperature of spontaneous combustion focus then especially the non-saturated hydrocarbons serve, i.e. binary indicator C_2H_4/C_3H_6. It follows from the above that the gases taken off in mine atmosphere indicate the average temperature of such a focus part from which they release.

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